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A HISTOLOGICAL STUDY ON THE NERVE DISTRIBUTION IN THE MESENTERY AND MESOCOLON SUPPLIED WITH THE SUPERIOR MESENTERIC ARTERY

by

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I INTRODUCTION

Physiological or histological studies concerning the sensory innervation of the alimentary canal have been reported by many investigators.

Using his Acetylcholine Method, CH. KIMURA (Assist. Prof. of our clinic) has proved the existence of sensation throughout the alimentary canal on the basis of physiological experiments. He also determined which of the vagal, thoracolumbar and sacral nerves had dominant innervation in each organ.

Pursuing the secondary degeneration of the peripheral nerves near the endings after section of the dorsal spinal roots and vagal nerve trunks, A. OTSU of our clinic has proved histologically the spinal and vagal afferent innervation of the stomach.

Moreover, TANAKA, MAKINO and others of our clinic have studied histologically on the afferent innervation of the alimentary canal in each portion.

The visceral afferent nerve fibers arised from the respective spinal segments are assembled in the origins of the coeliac, superior mesenteric and inferior mesenteric arteries, reorganized in those places, and then distributed in the regions supplied with the vessels. But the distribution of the reorganized nerves in the mesentery and mesocolon has not yet been elucidated enough.

Therefore, the author studied the distribution of the reorganized nerves in the mesentery and mesocolon supplied with the superior mesenteric artery of the dog, and attempted to clarify as for whether the segmental spinal innervation in the mesentery and the mesocolon may exist or not.

II MATERIALS AND METHODS

All the materials were obtained from adult dogs. The author used only fresh specimens taken from the mesentery and mesocolon which were resected operatively. After fixation for 3-4 weeks in 10% neutral formol solution, the specimens were frozen, sliced in thickness of 35-40 μ, fixed again in 10% neutral formol solution for several days, and then stained.

For examining the degeneration of the myelinated nerves, EHRLICH's acid hematoxyline method was used.

Considering the results of various experiments performed by many investigators from the anatomical or physiological standpoint, it can be assumed that most of the nerves of the mesentery and mesocolon are derived from the thoracolumbar and vagal nerves

Therefore, the spinal nerves and the vagus were cut at various points in my study in order to clarify the nerve distribution in the mesentery and the mesocolon, and the secondary degeneration of the myelinated nerves were examined.

The experimental animals were divided into following four groups according to the sites of which the nerve trunks were cut.

i) Group, in which the dorsal spinal roots were cut at a point distal to the spinal ganglia (abbreviated as "distal section group", below)

ii) Group, in which the dorsal spinal roots were cut at a point proximal to the spinal ganglia (abbreviated as "proximal section group", below)

iii) Group, in which the corresponding spinal ganglia were resected in the animals of the proximal section group 50 days after the same operation as described in ii) (abbreviated as "proximal-distal section group", below.)

iv) Group, in which the vagal nerve trunks were cut at a point distal to the nodular ganglion (abbreviated as "vagotomy group", below.)

According to the results of many experiments performed by investigators of our clinic, the secondary degeneration of peripheral nerves were clearly observed 5-6 days after posterior rhizotomy. Considering these results, the mesentery and the mesocolon of dogs were removed 5-6 days after operation. But in case of the vagotomy the specimens were taken 6-8 days after operations.

The animals were sacrificed by bloodletting, and the specimens were removed immediately.

According to the ramifications of the superior mesenteric artery, they were divided into such portions as shown in Table 1 in order to compare with the degeneration rates of the myelinated nerve fibers in each portion of the mesentery and the mesocolon.

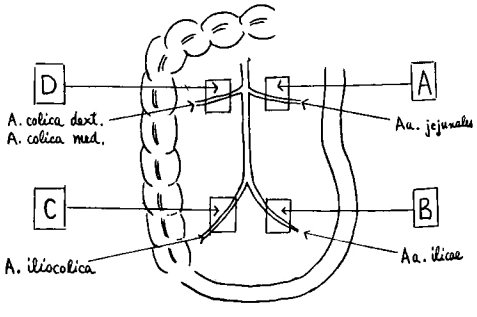
Ⅲ EXPERIMENTAL RESULTS

Using adult dogs as experimental animals, operations were performed as follows.

Laminectomy was performed under general anesthesia with thiopental sodium. The spinal canal was opened, and the dorsal and ventral roots were separated carefully from each other and only the dorsal roots were cut at a point distal or proximal to their ganglia on both sides. Vagus nerves were cut on one side in the neck distal to the ganglion nodosum.

After operation myelinated nerve fibers in the mesentery and the mesocolon

Table I



were broken at places giving a beadlike appearance, or stained unhomogenously, and sometimes degenerating granules were observed in them. They were clearly distinguishable from normal myelinated nerve fibers.

The number of the normal myelinated and the degenerated myelinated nerve fibers in 30 nerve bundles were counted in each portion of the mesentery and the mesocolon as shown in Table Ⅰ. Subsequently, the degeneration rates of the myelinated nerve fibers were calculated.

i) Distal section group

On the basis of the divisions where the posterior rhizotomy was done, the experimental animals were divided into following five groups.

Group 1 TH. 6-TH. 8

A few degenerated myelinated nerve fibers were found in A and B portions, while there were no degenerated nerve fibers in C and D portions. (Fig. 1, 2, 3)

Group 2 TH. 9- TH. 10

Degenerated myelinated nerve fibers were found in every portion of the mesentery and mesocolon. (Fig. 4)

Group 3 TH. 11-TH. 13

Many degenerated nerve fibers were found equally in each portion A, B, C and D. (Fig. 5, 6, 7)

Group 4. L. 1-L. 2

A few degenerated myelinated nerve fibers were found in every portion. (Fig. 8, 9)

Group 5 L. 3-L 4

No degenerated myelinated nerve fibers were found in any portion of the mesentery and the mesocolon.

The degeneration rate of the myelinated nerve fibers in each portion were given in Table Ⅱ.

Table II Degeneration rate of the myelinated nerves in each portion of the mesentery and mesocolon of the dog after posterior rhizotomy

	A	B	C	D
TH. 6-TH. 8	3.0%	3.7%	0%	0%
TH. 9-TH. 10	3.5%	3.0%	2.9%	3.8%
TH. 11-TH. 13	7.7%	8.2%	12.0%	11.0%
L. 1-L. 2	4.4%	2.7%	3.3%	3.1%
L. 3-L. 4	0%	0%	0%	0%

ii) Proximal section group

Experiments were divided into following four groups.

Group 1 TH. 6-TH. 8

Only one degenerated myelinated nerve fiber was found in A portion of the mesentery, while no degenerated nerve fibers were found in the others. (Fig. 10)

Group 2 TH. 9-TH. 10

One degenerated myelinated nerve fiber was found respectively in both A and B portions, while no degenerated nerve fibers were found in C and D portions. (Fig 11)

Group 3 TH. 11-TH. 13

A few degenerated myelinated nerve fibers were found in every portion of the mesentery and the mesocolon. (Fig. 11, 12)

Group 4 L. 1-L. 2

One degenerated myelinated nerve fiber was found respectively in both C and D portions, while there were no degenerated nerve fibers in A and B portion of the mesentery.

The degeneration rate of the myelinated nerve fibers in each portion were shown in Table Ⅲ.

Table III Degeneration rate of the myelinated nerve fibers in each portion of the mesentery and mesocolon after section of the dorsal spinal roots at a point proximal to the spinal ganglia

	A	B	C	D
TH. 6-TH. 8	0.3%	0%	0%	0%
TH. 9-TH. 10	0.4%	0.5%	0%	0%
TH. 11-TH. 13	0.6%	1.0%	0.5%	0.5%
L. 1-L. 2	0%	0%	0.4%	0.4%

iii) Proximal-distal section group

The experiments were divided into following four groups.

Group 1 TH. 6-TH. 8

Group 2 TH. 9-TH. 10

Group 3 TH. 11-TH. 13

Group 4 L. 1-L. 2

In every group, the degenerated myelinated nerve fibers were observed in the mesentery and mesocolon. These degenerated fibers were markedly deformed, showing a swelling and splitting like oil drops or granules. (Fig. 14-22)

The results were shown in Table Ⅳ.

Table IV Degeneration rate of the myelinated nerves in each portion of the mesentery and mesocolon of the dog

	A	B	C	D
TH. 6-TH. 8	2.3%	1.5%	0%	0%
TH. 9-TH. 10	2.3%	2.9%	1.9%	1.9%
TH. 11-TH. 13	8.6%	8.1%	6.2%	6.6%
L. 1-L. 2	2.5%	2.9%	3.2%	2.3%

Concerning the degeneration rate of the myelinated nerve fibers, same tendency as observed in the distal section group was demonstrated in each portion of the mesentery and mesocolon.

iv) Vagotomy group

A few degenerated myelinated nerve fibers were observed only in A portion of the mesentery which was removed 6 days after right vagotomy, while no degenerated nerve

fibers were found in the specimens which were removed 7 and 8 days after right or left vagotomy. These degenerated nerve fibers showed typical beadlike appearances and were clearly different from normal myelinated nerve fibers. (Fig. 23, 24)

Ⅳ DISCUSSION

LANGLEY, RANSON, SHEEHAN and other investigators have maintained, from the histological or physiological point of view, that visceral afferent nerves which pass through the sympathetic trunk have their trophic cells in the dorsal root ganglia and reach the effector organs without intermittent neurons on the way, and that most of them consist of myelinated nerve fibers.

NEUMANN, WHITE, KUBO, ASAI and others described visceral afferent nerves in the vagus, and RANSON and others reported that visceral afferents of the vagus have their cells in the ganglion nodosum.

When the dorsal roots of the spinal cord or the vagus nerves are cut at a point distal to each ganglion, only these visceral afferent nerves should, therefore, be degenerated throughout their course.

Examining the secondary degeneration of the peripheral nerves after section of the nerve trunk, many investigators of our clinic have studied the afferent innervation in the various regions of the digestive tract; i. e., TANAKA in the esophagus, OTSU in the stomach, MAKINO in the small intestine and cecum, LEE in the colon, WANG in the sigmoid and rectum.

Performing various kinds of the degeneration experiments, the author studied the nerve distribution of the mesentery and mesocolon of the dog.

(1) Distribution of the myelinated nerves of spinal origin

In regard to the afferent innervation of the regions supplied with the superior mesenteric artery, MAKINO and LEE of our clinic described that the afferent nerve fibers of the small intestine and cecum are derived from the dorsal roots of the spinal cord between TH. 5-L. 4, and those of the ascending colon between TH. 9-L. 4.

The results of the histological experiments in the distal section group are as follows:

The myelinated nerve fibers in the mesentery and mesocolon are derived from the dorsal roots of the spinal segments between TH. 6-L. 2, but most of them from TH. 11-TH. 13. The results of these experiments are approximately similar to those of the experiments by MAKINO and LEE.

Comparing the degeneration rates of the myelinated nerve fibers in each portion of the mesentery and mesocolon, no significant difference is observed in groups (TH. 9-TH. 10), (TH. 11-TH. 13) and (L. 1-L. 2) as shown in Table Ⅱ. While in group (TH. 6-TH. 8) no degenerated myelinated nerve fibers are found in C and D portions.

It can be seen from the above that the myelinated nerve fibers derived from the dorsal spinal roots between TH. 9-L. 2 are distributed equally in each portion of the mesentery and mesocolon.

KIMURA has described that, from his physiological and clinical investigations using Acetylcholine method, the local signs of visceral pain from the small intestine and cecum gave broad overlapping areas on the abdominal surface from the middle portion of the

epigastrium to the surrounding areas of the navel. That the sites of pain originating small intestine and cecum are overlapped is considered to be due to the equal distribution of the nerves of spinal origin in the regions supplied with the superior mesenteric artery, as shown in the results of the present histological experiments.

In the proximal section group, a few degenerated myelinated nerve fibers were found in each portion of the mesentery and mesocolon. This fact apparently indicates the existence of the myelinated nerve fibers which have their cells in the spinal cord and pass through the dorsal spinal roots without interruption in the spinal ganglia. But these nerve fibers were very few in number as compared with those of the distal section group.

K. KURE and S. OKINAKA have maintained the existence of the spinal parasympathetic nerves in the dorsal roots of the spinal cord. According to their opinion, these nerves have their trophic cells in the spinal cord and pass through the dorsal spinal roots with changing their neurons in the spinal ganglia, and their preganglionic and postganglionic fibers are myelinated nerve fibers.

S. KAHR and D. SHEEHAN proved the existence of the efferent nerve fibers in the dorsal roots of the spinal cord, but they stated that these nerve fibers pass through the dorsal spinal roots without intermittent neurons in the spinal ganglia.

Determination can hardly be made as to whether the degenerated myelinated nerve fibers observed in the proximal section group may belong to the spinal parasympathetic system or not.

In the proximal-distal section group, in the first place, the nerve fibers passing through the dorsal spinal roots without interruption in the spinal ganglia had certainly been disappeared by section of the dorsal spinal roots at a point proximal to the spinal ganglia. Subsequently, the degeneration of the myelinated nerve fibers having their cells in the spinal ganglia were examined. As indicated in Table Ⅳ the results obtained in this group almost coincide with those of the experiments in the distal section group.

It is clear from these data that most of the degenerated myelinated nerve fibers in the mesentery and mesocolon have their cells in the dorsal spinal ganglia.

(2) Distribution of the myelinated nerves of vagal origin

RANSON, FOLEY, ALPERT and others insist from the physiological standpoint that the visceral afferent nerve fibers are contained in the vagus nerve.

According to TANAKA and OTSU, vagal afferent nerve fibers can be observed histologically in the esophagus and stomach, and their innervation is more dominant than the sympathetic sensory innervation.

As to vagal afferent innervation in the regions supplied with the superior mesenteric artery, MAKINO found no vagal afferent nerve in jejunum, ileum and cecum, but in the ascending colon LEE found them a very few. SUZUKI reported that, from the results of his histological experiments, only one degenerated myelinated nerve fiber was found in the middle portion of the small intestine after right vagotomy, and KOSEKI found no myelinated nerve fibers of vagal origin in the ileocoecal region.

The author examined as for whether the myelinated nerve fibers derived from the vagus are distributed in the mesentery and mesocolon of the dog, and the following results were obtained.

A few degenerated myelinated nerve fibers were found only in A portion of the mesentery which was removed 6 days after right vagotomy, while no degenerated myelinated nerve fibers were found in the other cases of vagotomy. It is reasonable to deduce from the above that the myelinated nerve fibers of vagal origin are a very few in the regions supplied with the superior mesenteric artery.

Consequently, the thoracolumbar innervation is more dominant than the vagal innervation in the mesentery and mesocolon of the dog.

V SUMMARY AND CONCLUSION

Examining the secondary degeneration of the myelinated nerves after section of the nerve trunks, the author has studied the nerve distribution in the mesentery and the mesocolon supplied with the superior mesenteric artery.

The results are summarized as follows:

1) The myelinated afferent nerve fibers of spinal origin in the mesentery and mesocolon supplied with the superior mesenteric artery are derived from the dorsal roots between TH. 6-L. 2, but mainly from TH. 11-TH. 13.

2) The distribution of the myelinated nerves derived from the dorsal roots between TH. 9-L. 2 spinal segments are almost equally in each portion of the mesentery and the mesocolon, and there are no significant differences with the degeneration rate of the myelinated nerves in each portion.

3) The myelinated nerves derived from the dorsal roots between TH. 6-TH. 8 spinal segments are distributed only in the mesentery of the upper and middle portions of the small intestine, and none of them are distributed in the mesocolon.

4) A few myelinated nerve fibers, which have their cells in the spinal cord and pass through the dorsal spinal roots without interruption at the spinal ganglia, are found in the mesentery and the mesocolon.

5) A very few myelinated nerve fibers derived from the vagus are observed in the mesentery.

ZUSAMMENFASSUNG

Durch die sekundäre Degeneration der peripheren Nervenfasern nach der Durchtrennung der Nervenstämme studierte der Verfasser über die Verteilung der markhaltigen Nervenfasern in dem Mesenterium und Mesokolon des Hundes.

Ergebnisse werden in folgenden Sätzen zusammengefasst:

1) Die markhaltige Nervenfasern des Mesenteriums und Mesokolons entspringen aus den hinteren Wurzeln zwischen den TH. 6 bis L. 2 Segmenten, vorwiegend aus den TH. 11 bis TH. 13 Segmenten.

2) Die über die hinteren Wurzeln zwischen den TH. 9 bis L. 2 Segmenten laufenden markhaltigen Nervenfasern verteilen sich gleichmässig in jedem Abschnitt des Mesenteriums und Mesokolons.

3) Die über die hinteren Wurzeln zwischen den TH. 6 bis TH. 8 Segmenten laufenden markhaltigen Nervenfasern verteilen sich nur in dem Mesenterium der kranialen und mittleren Abteilung des Dünndarmes.

4) Die markhaltige Nervenfasern, welche ihren Ursprungskernen in dem Rückenmark haben und über die hinteren Wurzeln ohne Unterbrechung in den Spinalganglien durchgehen, sind in dem Mesenterium und Mesokolon ein wenig zu beobachten.

5) Ein kleiner Teil der markhaltigen Nervenfasern gehört dem Vagus an.

(I am much indebted to Assist. Prof. Dr. Chuji Kimura for his kind guidance throughout this study and I wish to express my deep thanks toward Dr. T. Sera and Dr. Y. Yasumoto for their help during these experiments.)

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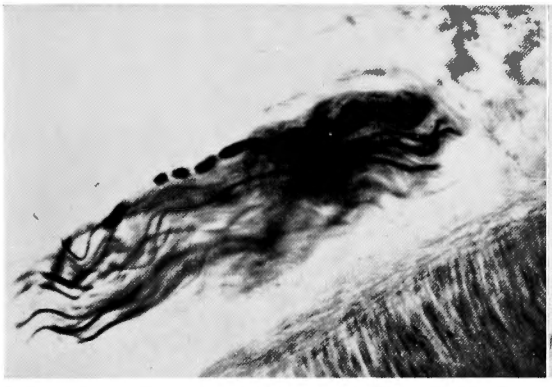

Fig. 1 A degenerated thick nerve fiber in a bundle along the blood vessel of the portion A of the mesentery (Distal section group, TH.6-TH.8) ×200

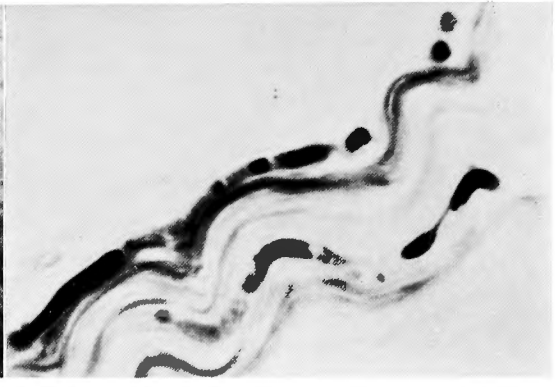

Fig. 2 Degenerated thick nerve fibers showing oil drops appearance in the portion A of the mesentery (Distal section group, TH.6-TH.8) ×400

Fig. 3 A degenerated nerve fiber in the portion B of the mesentery (Distal section group, TH.6-TH.8) ×400

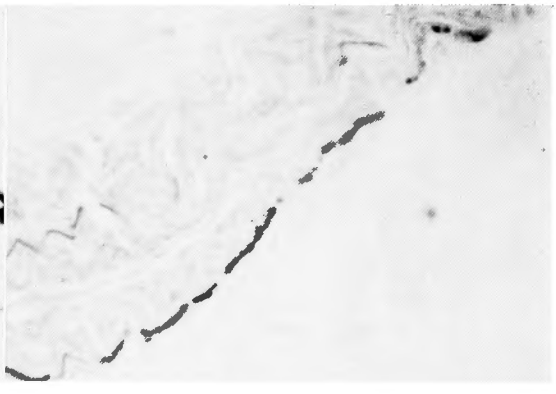

Fig. 4 A degenerated small sized nerve fiber in the portion C of the mesentery (Distal section group, TH.9-TH.10) ×400

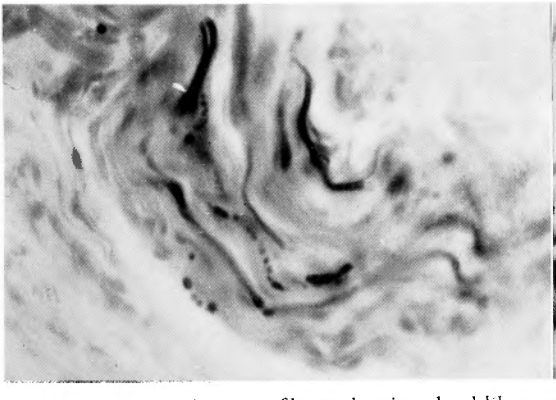

Fig. 5 Degenerated nerve fibers showing bead-like appearance in the portion B of the mesentery (Distal section group, TH.11-TH.13) ×400

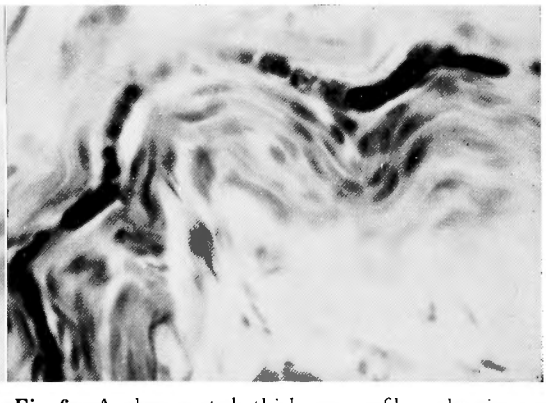

Fig. 6 A degenerated thick nerve fiber showing unhomogenous staining in the portion C of the mesentery (Distal section group, TH.11-TH.13) ×400

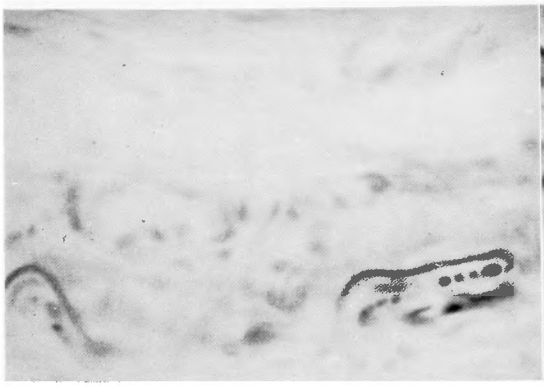

Fig. 7 A degenerated nerve fiber in a bundle along the blood vessel of the portion D of the mesocolon (Distal section group, TH.11-TH.13) ×400

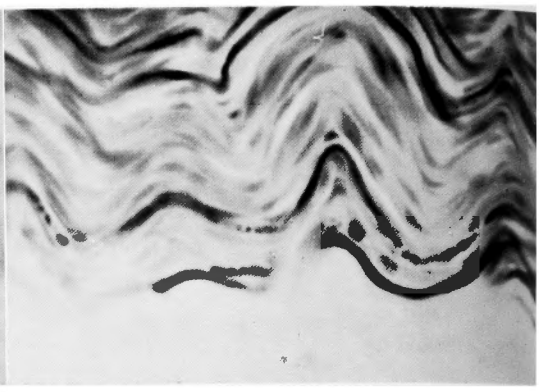

Fig. 8 Degenerated nerve fibers in the portion C of the mesentery (Distal section group, L.1-L.2) ×400

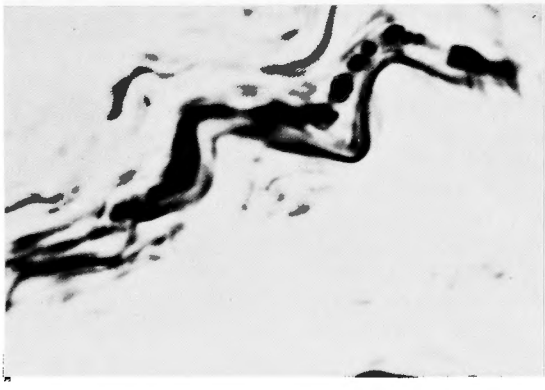

Fig. 9 A degenerated nerve fiber in the portion B of the mesentery (Distal section group, L.1-L.2) ×400

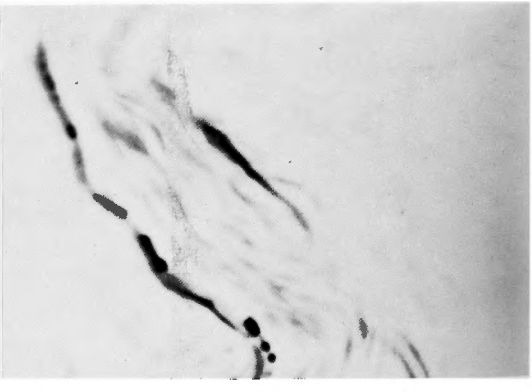

Fig.10 A degenerated nerve fiber in the portion A of the mesentery (Proximal section group, TH.6-TH.8) ×400

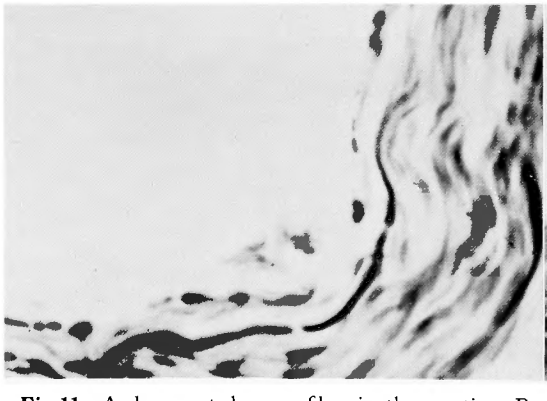

Fig.11 A degenerated nerve fiber in the portion B of the mesentery (Proximal section group, TH.9-×TH.10) 400

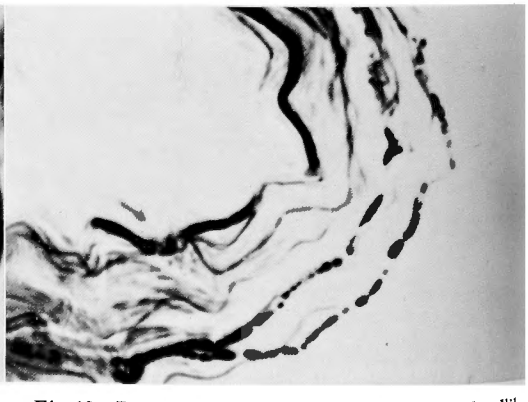

Fig.12 Degenerated nerve fibers showing beadlike appearance in the portion A of the mesentery (Proximal section group, TH.11-TH.13) ×200

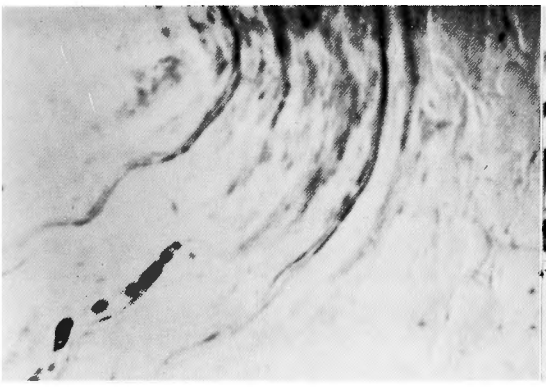

Fig.13 A degenerated nerve fiber in the portion D of the mesocolon (Proximal section group, TH.11-TH.13) ×400

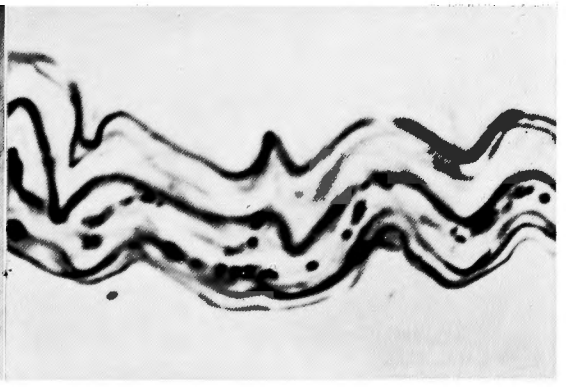

Fig.14 Degenerated nerve fibers showing beadlike appearance in the portion A of the mesentery (Proximal-distal section group, TH.6-TH.8) ×400

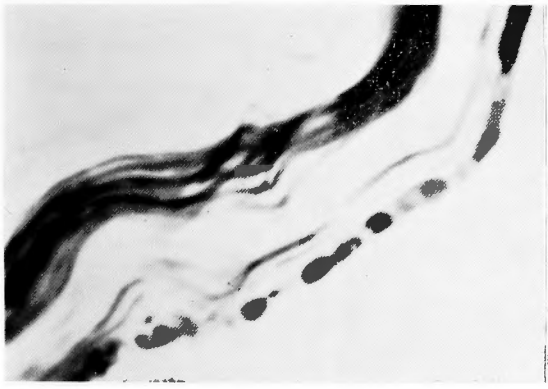

Fig.15 A degenerated nerve fiber in the portion B of the mesentery (Proximal-distal section group, TH.9-TH.10) ×400

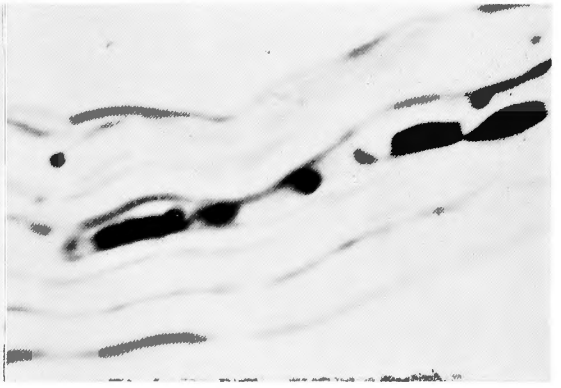

Fig.16 A degenerated thick nerve fiber showing swelling in the portion C of the mesentery (Proximal-distal section group, TH.9-TH.10) ×400

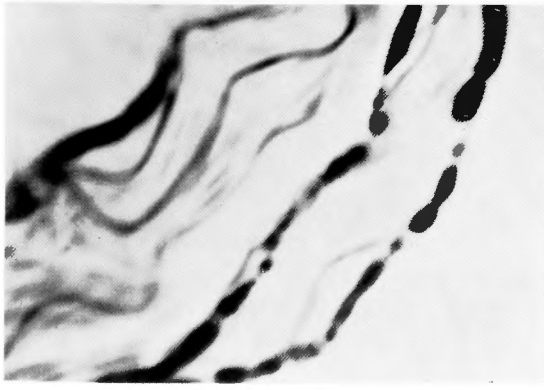

Fig.17 Degenerated nerve fibers in the portion A of the mesentery (Proximal-distal section group, TH.11-TH.13) ×400

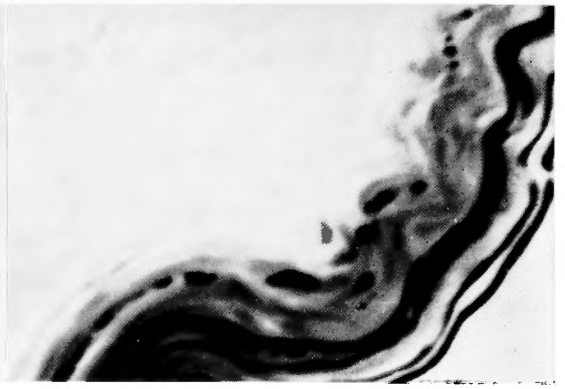

Fig.18 A degenerated nerve fiber in the portion B of the mesentery (Proximal-distal section group, TH.11-TH.13) ×400

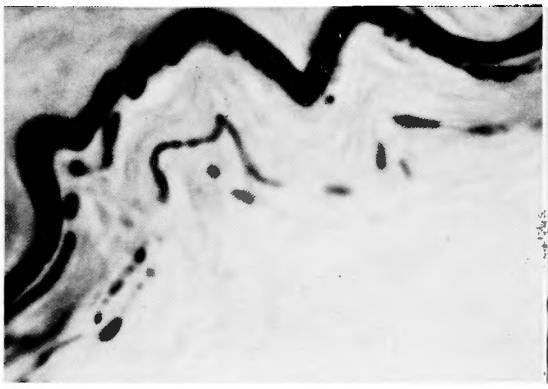

Fig.19 Degenerated nerve fibers in the portion C of the mesentery (Proximal-distal section group, TH.11-TH.13) ×400

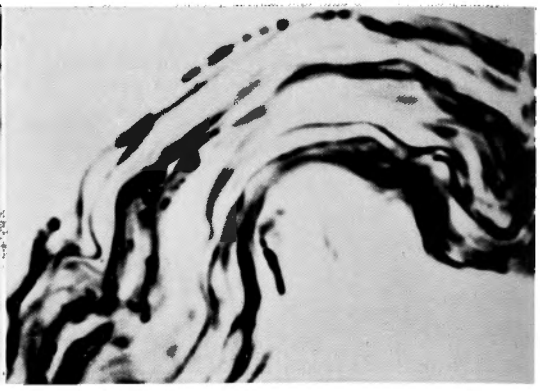

Fig.20 Degenerated nerve fibers in the portion D of the mesocolon (Proximal-distal section group, TH.11-TH.13) ×400

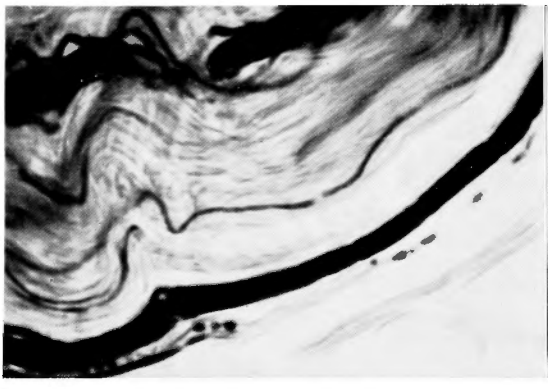

Fig.21 A degenerated nerve fiber in the portion A of the mesentery (Proximal-distal section group, L.1-L.2) ×400

Fig.22 Degenerated nerve fibers in the portion C of the mesentery (Proximal-distal section group, L.1-L.2) ×400

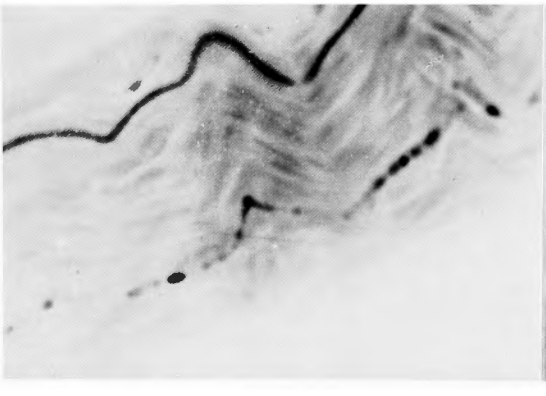

Fig.23 A degenerated nerve fiber showing beadlike appearance in the portion A of the mesentery (Vagotomy group) ×400

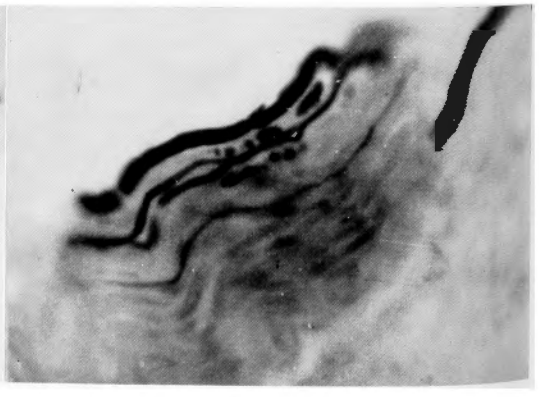

Fig.24 Degenerated nerve fibers in the portion A of the mesentery (Vagotomy group) ×400

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和文抄録

上腸間膜動脈領域の腸間膜及び結腸間膜内の神経分布に関する組織学的研究

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成犬を用いて，1) 脊髄神経節より末梢に於て脊髄後根（TH.6-L.4）を切断，2) 脊髄神経節より中枢に於て脊髄後根（TH.6-L.2）を切断，3) 脊髄神経節より中枢に於て脊髄後根（TH. 6-L. 2）を切断し，50日後に当該脊髄神経節を切除，4) 節状神経節の末梢に於て迷走神経を切断，の4群の実験を行い，Ehrlich 氏神経髄鞘染色法を用いて，上腸間膜動脈領域の腸間膜及び結腸間膜内の有髄神経の二次的変性を追求し，これ等の結果から上腸間膜動脈領域の腸間膜，結腸間膜内の有髄神経の支配系統並びにその分布状態に就いて，次の結論を得た．

1) 上腸間膜動脈領域の腸間膜，結腸間膜内の有髄神経の大部分は（TH.6-L.2）の脊髄後根に由来し，この中（TH.11-TH.13）の脊髄後根に由来するものが最も優勢である．

2) （TH.9-L.2）の脊髄後根に由来する有髄神経は腸間膜，結腸間膜内の空腸動脈周囲，回腸動脈周囲，回結腸動脈周囲，右及び中結腸動脈周囲の各領域にほぼ平等に分布する．各領域に於ける有髄神経の変性率に有意の差を認めなかつた．

3) （TH.6-TH.8）の脊髄後根に由来する有髄神経は，腸間膜内の空腸動脈周囲領域，回腸動脈周囲領域にのみ分布し，回結腸動脈周囲領域，右並びに中結腸動脈周囲領域には分布を認めなかつた．

4) 脊髄内に神経細胞を有し，脊髄神経節に於てNeuronを交替せずに脊髄後根を通過する有髄神経が，腸間膜，結腸間膜内の各領域に少数認められた．

5) 迷走神経由来の有髄神経は，腸間膜内の空腸動脈領域に少数認められたが，その他の領域には認められなかつた．